

Analysis of the application efficiency of the slab-pile foundation using the example of a two-layer base

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Abstract. The purpose of this work was to determine the increase of the limit load when resting the foundation slab on the ground at a different pitch of piles and their different length. The main task is to calculate the combined pile-slab foundation. The hypothesis was that when the foundation slab in the work, the bearing capacity of the entire structure increases. This foundation was calculated using the Plaxis 3D design software complex. In this article, we have determined the value by which the ultimate load on the combined pile-slab foundation increases when the slab rests on soil.

1 Introduction

Combined pile-slab foundation - is a foundation in which part of the load is transmitted through through the sole of the slab grillage, and part of the load directly through the piles.

This type of foundations is used to reduce the total and uneven precipitation of buildings and structures. It is also possible to use design solutions both with a constant pile pitch in the plan, and with a variable. The combined pile-slab foundation can include absolutely any type of pile.

CPS can be used only under a condition if the base of pile bushes and of piles fields is composed of either dense sand and medium-density sands or clay soils with flow index I_L not more than 0.5 and deformation modulus $E > 8$ MPa. If these conditions are not met the foundation is considered as a pile with a slab grillage.

Calculations of the combined pile-slab foundation should include the following:

- determination of forces in piles, both ordinary and to extreme, as well as in the grillage plate;
- determination of the load parts that are perceived by the piles and the slab.

The following types of interactions must also be taken into account in the calculation:

- piles with the surrounding them soil;

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- slabs with soil;
- mutual influence of piles through the ground;
- mutual influence of piles and grillage.

The pitch of the piles, as well as the determination of their length is carried out based on the calculation of deformations. At the same time, the permissible values of the sediment, heeling and the relative difference in the sediment of the constructed structure must be provided.

The calculation of the combined pile-slab foundation can be carried out using both geotechnical programs based on numerical modeling, as well as slabs on an elastic base using a variable in plan coefficient of elastic ground resistance, the mean value of which can be assigned both from a spatial nonlinear calculation and by solving an axisymmetric problem for a cell including a pile and its surrounding soil mass.

Also, for ensure the maximum inclusion of the foundation slab in the work, when designing, special events should be provided for the preparation of the future foundation. One of these measures is the arrangement of piles with power concrete preparation.

Piles of different diameters and lengths can be used when designing a combined pile-slab foundation. But pile lengths should not differ by more than 30%.

This type of foundation has the following advantages:

- provide technical conditions for construction in problem or wetland areas;
- the effect of heaving loads decreases or disappears;
- Less earthworks, which in some cases are not carried out at all;
- it is possible to build on slopes.

The disadvantages include the following:

- increases the cost of construction;
- high labor intensity of construction

2 Calculation of combined pile-slab foundation

In order to check the performance of the slab part in the combined pile-slab foundation, we have created two design schemes.

Design diagrams are a pile field made of bored piles with a diameter of 450 mm with a pitch of 3 -6 diameters (1.35 m - 2.7 m) of piles and a slab part with a thickness of 500 mm. The size of the slab part is 27.9 m x 27.9 m.

In the first version, the plate represents a high grillage, and in the second the plate rests directly on the ground.

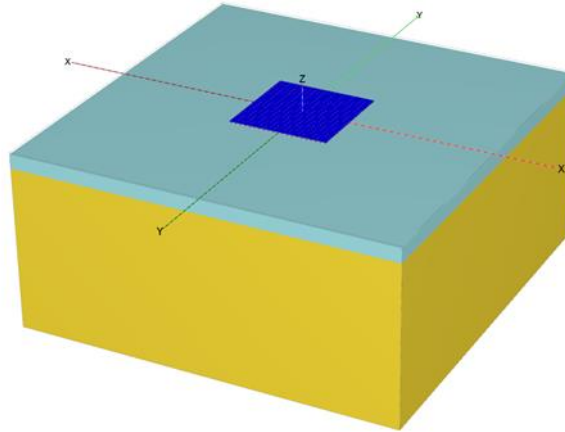


Fig. 1. Calculation diagram

In order to check the efficiency of the plate part, we changed the modulus of deformation of the upper soil, which in one case was 4 Mpa, and in the other 10 Mpa.

Since pile foundations are used in weak soils, we have modeled the following soil conditions:

The upper layer is high-mineral sapropel with the following strength and deformation characteristics:

Table 1. Accepted engineering and geological conditions

№	Name	ρ (г/см ³)	c (кПа)	ϕ (°)	E (МПа)	e	v
1	High-mineral sapropel	1,15	11	10	4/10	3,112	0,377
2	Medium-sized sand	1,65	0,7	31	27	0,639	0,316

The power of the upper layer is 4 m.

When calculating the combined pile foundation, the bearing capacity of the piles should initially be determined.

The bearing capacity of piles was determined using tables SP 24.13330.11.

2.1 Calculation of bored piles

The length of the piles is 10 and 12 m. The pile cuts thickness weak soil 4 m thick and enters the sands of medium size by 6 and 8 m, respectively. Only the bottom layer is considered in the load calculation.

The bearing capacity of the pile is calculated by the formula:

$$F_d = \gamma_c * (\gamma_{R,R} * R * A + \gamma_{R,f} * u * \sum f_i * h_i) \quad (1)$$

where γ_c - coefficient of pile working conditions; in case of its resting on clay soils with moisture degree $S_r = 0,85$ and on loessial soils $-0,8$, in other cases $-\gamma_c = 1$;

$\gamma_{R,R}$ - reliability factor for soil resistance under the lower end of the pile; $\gamma_{R,R} = 1$ in all cases, except for piles with camouflage widening and bored pile according to 6.5, e, for which this coefficient should be taken equal to 1.3, and piles with widening, arranged by mechanical drilling of soil concreted dry $\gamma_{R,R} = 0,5$ and concreted by underwater method, for which $\gamma_{R,R} = 0,3$;

R - design soil resistance under the lower end of the pile, kPa, accepted as per 7.2.7; and for the stuffed pile made on the technology specified at 6:4a,b - according to table 7.2 [1];

A - pile support area, m², taken equal to:

for padded and drilled piles without widening - pile cross-sectional area;

for padded and drilled piles with widening - widening cross-sectional area in place of the largest diameter;

for pile-shells filled with concrete - gross shell cross-sectional area;

u - perimeter of pile shaft cross-section, m;

$\gamma_{R,f}$ - coefficient of soil working conditions on the pile side surface, depending on the well formation method and concreting conditions and accepted as per Table 7.6 [1];

f_i - design resistance of the i-th layer of soil on the side surface of the pile shaft, kPa, accepted as per Table 7.3 [1];

hi - thickness of the i-th layer of soil.

Table 2. Determination of pile bearing capacity 10 m

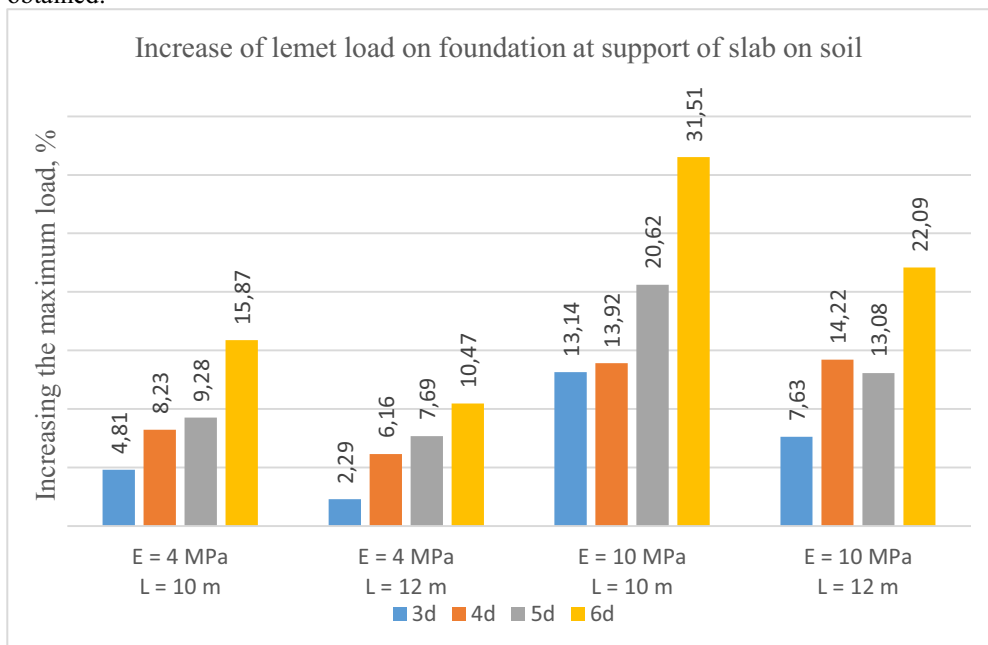
Coefficient of pile working conditions	γ_c	1	
Reliability coefficient for the resistance of the soil under the lower end of the pile	$\gamma_{R,R}$	1	
Coefficient working conditions soil on pile side surface	$\gamma_{R,f}$	0,7	
Pile diameter, m	d	0,45	m
Depth of inception lower end of pile, m	h	10	m
Design soil resistance under the lower end of the pile	R	1361,7	kH/m ²
Pile support area, m ²	A	0,159	m ²
Perimeter of cross section of pile shaft, m;	u	1,414	m
Bearing capacity of pile	Fd	572	kH

Table 3. Determination of pile bearing capacity 12 m

Coefficient of pile working conditions	γ_c	1	
Reliability coefficient for the resistance of the soil under the lower end of the pile	$\gamma_{R,R}$	1	
Coefficient working conditions soil on pile side surface	$\gamma_{R,f}$	0,7	
Pile diameter, m	d	0,45	m
Depth of inception lower end of pile, m	h	12	m
Design soil resistance under the lower end of the pile	R	1601,6	$\kappa\text{H}/\text{M}^2$
Pile support area, m ²	A	0,159	M^2
Perimeter of cross section of pile shaft, m;	u	1,414	m
Bearing capacity of pile (sandy soil)	Fd	741	κH

Then the load-bearing capacity of the pile was entered into the Plaxis 3D program.

When calculating in the Plaxis 3D software package, the following results were obtained:



From this graph we can see:

1. With the module of deformation of the upper layer of soil $E = 4$ MPa at different pile pitch, the increase in load on the foundation when resting the slab on the base is from 4.81% to 15.81% with a pile length of 10 m and from 2.29% to 10.47% with a pile length of 12 m.
2. With a sapropel deformation module $E = 10$ MPa, the load increase was from 13.14% to 31.51% and from 7.63% to 22.09% with a pile length of 10 and 12 m, respectively.
3. With deformation module the upper soil layer $E = 4$ MPa and 10 MPa with an increase in the pitch of the piles, the percentage of load that the plate receives increases at different pile lengths. The exception is step 4d and 5d, with sapropel module $E = 10$ MPa and pile length 12 m.
4. It can also be seen on the graph identical under the same conditions, the increase in load with a pile length of 10 m occurs faster than with a pile length of 12 m.

3 Conclusions

The calculations showed the efficiency of the combined pile-slab foundation compared to the pile foundations.

As calculations show, naturally with an increase in the module, the deformation in the base of the slab foundation increases, the percentage of load perceived by the slab. The same conclusion can be made when the pitch of the piles increases.

References

1. SP 24.13330.2011 Pile foundations.
2. SP 22.13330.2016 Soil bases of buildings and structures.
3. D.YU. Chunyuk, N.O. Kurilin. *Effectiveness evaluation of combined piled-raft foundation constituents operation*. SR, **16**, p. 6-10, (2016).
4. Chunyuk D.YU., Kurilin N.O. Possible methods of calculation of combined pile-raft foundations. SR, **18**, 11-17, (2016).
5. Ladyzhenskiy I.G., Sergiyenko A.V. Combined pile-plate foundations (KSPF) and combined plate-pile foundations – KPSF) - development prospects. HAT, **6**, 132-135, (2014).